Transmit Diversity Gain for Wireless Communications Networks

Field of the Invention

[01] This invention relates generally to wireless communication networks, and more particularly to adaptive transmit diversity in such networks.

Background of the Invention

[02] Transmit diversity is one of the key technologies that define third generation wireless communication systems, such as cellular telephone networks. In such systems, spatial diversity is introduced into the signal by transmitting the signal through multiple antennas. Spatial diversity reduces the effects of channel fading by providing multiple independent copies of the signal at the receiver. With transmit diversity, the probability that all copies fade simultaneously in the channel is very small. As a result, the system performance is improved.

[03] Transmit diversity can use multiple spatially separated antennas, as well as various temporal or frequency modulation techniques, or combinations of these techniques.

[04] Space time transmit diversity (STTD) is an open loop transmit diversity technique. STTD has been adopted by the 3rd generation partnership project (3GPP) for wideband code division multiple access (W-CDMA) standards. Open loop

means that there is no feedback about channel conditions from the receiver to the transmitter.

[05] Figure 1 shows a basic structure of a conventional STTD system 100. The system uses two transmit antennas 103, and one receive antenna 104. In such a system, the transmitter generates a stream of data to be transmitted as pairs of symbols X_1 and X_2 110. Each pair of symbols is fed to a symbol level STTD encoder block 101 of the transmitter. An output matrix 111 of the encoder 101 is

[06] $$C_1 = \begin{bmatrix} X_1 & X_2 \\ X_2^* & -X_1^* \end{bmatrix}, \qquad (1)$$

where * denotes a complex conjugate. Transmit symbols, in a left-to-right order, of the rows, in a top-to-bottom order, are fed to the corresponding different transmit antennas, as shown in Figure 1. That is, the transmit symbols X_1, X_2 of the first row all go to the first transmit antenna, and the transmit symbols $X_2^*, -X_1^*$ of the second row all go to the second transmit antenna.

[07] After passing through a wireless channel 115, the channel impulse responses h_1 and h_2 118 are detected and measured by the decoder 102 having a single antenna 104.

[08] In general, this type of transformation maximizes the diversity gain in the case of two transmit antennas. Because the diversity gain is proportional to the number of transmit antennas, a higher number of transmit antennas are required to achieve higher diversity gains and to improve the performance of the system.

[09] This is especially true in a downlink channel because a base station can typically incorporate a large number of transmit antennas. However, the 3GPP W-CDMA standards for the STTD scheme limits the transmitter to two transmit antennas. Therefore, any other transmit diversity technique for 3GPP, with a larger number of antennas, must achieve backward compatibility with systems with two transmit antennas.

[010] Therefore, it is desired to provide STTD transmitters with more than two transmit antennas, while achieving backward compatibility with prior art two antenna 3GPP W-CDMA systems.

Summary of the Invention

[011] A method and system increases transmit diversity gain in a wireless communication system. The system includes a transmitter with 2^N transmit antennas, where N is greater than one, and a receiver with one or more receive antenna. The transmitter includes N stages connected serially to each other.

[012] The first stage is a symbol level space-time transmit diversity encoder.

[013] Each of the next N-1 stages is a block level space-time transmit diversity encoder, for a total of N stages. The last stage is connected to the 2^N antennas.

[014] The transmitter generates pairs of symbols in a form X_1 and X_2. The pairs of symbols are encoded by the first stage to produce a $2^1 \times 2^1$ output matrix C.

[015] Then, in each next block level stage n, the $2^{n-1} \times 2^{n-1}$ output matrix of a previous stage is encoded to a $2^n \times 2^n$ output matrix, until a final output matrix has 2^N rows of transmit symbols.

[016] The transmit symbols of the final output matrix are fed, in a left-to-right order, for each row, in a top-to-bottom order, to a corresponding different one of the 2^N transmit antennas. A transmit weight is aplied to each transmit symbol before transmitting the transmit symbol.

Brief Description of the Drawings

[017] Figure 1 is a block diagram of a prior art STTD system with two transmit antennas and one receive antenna;

[018] Figure 2 is a block diagram of a STTD transmitter with 2^N transmit antennas according to the invention; and

[019] Figure 3 is a block diagram of block level STTD encoders connected serially.

Detailed Description of the Preferred Embodiment

[020] As shown in Figure 2, the invention provides a transmitter 200 with 2^N transmit antennas 201, where N is an integer value greater than one. This is an extension of the prior art STTD transmitter with two antennas, i.e. N equals one. For the example transmitter in Figure 2, N equals two, so there are four transmit antennas 204.

[021] In order to be backward compatible with the prior art STTD system of Figure 1, a transmit signal is generated as a stream of pairs of symbols. Each pair of symbols is denoted generally by X 110. Each pair of symbols is first encoded by a symbol level STTD encoder 210 as a matrix C 212 with two rows.

[022] According to the invention, a pair of consecutive symbol pairs (X_1, X_2) and (X_3, X_4) encode 210 to a pair of matrices C_1 and C_2

$$C_1 = \begin{bmatrix} X_1 & X_2 \\ X_2^* & -X_1^* \end{bmatrix} \text{ and } C_2 = \begin{bmatrix} X_3 & X_4 \\ X_4^* & -X_3^* \end{bmatrix}. \qquad (2)$$

[023] Next, a 4 x 4 matrix of transmit symbols T 221 are generated for the four antennas 204 from each pair of matrices C_1 and C_2 by a block level encoder 220. That is, each matrix C is treated as an element for the block level STTD encoding operation 220.

[024] As a result of the block level encoding 220, the matrix T 221 is

$$T_1 = \begin{bmatrix} C_1 & C_2 \\ C_2^* & -C_1^* \end{bmatrix} = \begin{bmatrix} X_1 & X_2 & X_3 & X_4 \\ X_2^* & -X_1^* & X_4^* & -X_3^* \\ X_3^* & X_4^* & -X_1^* & -X_2^* \\ X_4 & -X_3 & -X_2 & X_1 \end{bmatrix}. \qquad (3)$$

[025] Transmit symbols, in a left-to-right order, of each row of the matrix T 221, in a top-to-bottom order, are fed to the corresponding different transmit antennas 204. That is, the transmit symbols X_1, X_2, X_3, X_4 go to the first antenna, and the transmit symbols $X_2^*, -X_1^*, X_4^*, -X_3^*$ to the second antenna, and so forth.

[026] As further shown in Figure 2, the performance of the system can be further improved by applying optional weights 230 to each transmit symbol. The weight at the i^{th} antenna is denoted by W_i for i =1, 2, ..., 2^N. The value of W_i is based on channel conditions.

[027] Some techniques to determine the transmit weights are addressed in the literature. The most commonly used techniques are the water-filling algorithm and eigen-mode algorithm, see Valaee et al., "Resource Allocation for Video Streaming in Wireless Environment," IEEE International Symposium on Wireless Personal Multimedia Communications (WPMC 02), October 2002. Both techniques select the transmit weights based on the channel conditions. If maximum received signal-to-noise ratio at each receive antenna is desired, then the eigen-mode algorithm is favorable.

[028] The channel conditions can be estimated or measured in a receiver and fed back to the transmitter. In the case the channel condition is fed back, then the the system operates in closed loop, which is different from a conventional STTD system. However, if identical real-value weights are applied at each transmit antenna, then backward compatibility is maintained.

[029] As shown in Figure 3, this process and structure can be generalized for N= 2, ..., n, ..., N, i.e., four, eight, sixteen, etc., transmit antennas by adding (N-1) block level STTD encoding blocks 220, connected serially, after the symbol level STTD encoder 210.

[030] During each next block level STTD operation, each pair of matrices from an ouput of a previous encoding stage is treated as an input element in the subsequent block level STTD encoding. The resulting 2^Nx 2^N output matrix 300 is a final encoding matrix for transmission. Transmit symbols of the rows of the final matrix 300 are fed to the 2^N antennas, in a top-to-bottom order, as shown.

[031] It is noted that the pairs of transmit symbols taken from the two top rows of the encoding matrix in equation (3) are identical to the output of the symbol level STTD 210, no matter how many block level STTD blocks are added. Therefore the backward compatibility with priot art two antenna STTD transmitters is achieved.

[032] Therefore, a prior art receiver can process the received signal without having to know the number of encoding stages that were used by the transmitter. However, if the receiver is aware that in addition to the single symbol level encoding

stage, one or more block level encoding stages were also used, then the increased diversity gain due to those additional stage can provide better performance.

[033] It should be noted that the diversity gain can be further improved by increasing the number of antennas at the receiver.

[034] Although the invention has been described by way of examples of preferred embodiments, it is to be understood that various other adaptations and modifications can be made within the spirit and scope of the invention. Therefore, it is the object of the appended claims to cover all such variations and modifications as come within the true spirit and scope of the invention.